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A deſcription of the experiments intended to illuſtrate a courſe of lectures on natural philoſophy; read in the Obſervatory, at Trinity College, Cambridge.

By George Atwood, M.A.

ERRATA.

P. 3. line 15, *for* counterpoize, *read* counterpoiſe. — P. 17. l. 2. *read* perpendicular to the horizon. — P. 21. l. 2. *for* up an immeſed tube, *read* up in an immerſed tube. — P. 25. l. 19. *for* cubicin inch, *read* cubic inch. — P. 27. l. 7. *for* ſpecifick, *read* ſpecific. — l. 20, at the end, *dele* or a little.

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A DESCRIPTION, &c.

MECHANICS.

Experiment I.

If light bodies float upon the ſurface of water contained in a glaſs veſſel, they are obſerved to be attracted toward the ſide of it.

That power (whatever be the cauſe of it) by which bodies are impelled toward each other, has been termed by Sir I. Newton, and others, attraction, gravity, or ſometimes gravitation, which only ſignify the different modes in which the ſame principle operates. Thus the ſmaller body is ſaid to gravitate toward the larger, and the larger to attract the ſmaller.

Exp. II.

Glaſs planes, held contiguous to each other, are obſerved to attract the water in which they are immerſed, and to raiſe it up between them, above the level of the external water.

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Exp. III.

Capillary tubes attract the water in which they are immerſed, and raiſe it above the level of the external water.

Exp. IV.

A copper-wire, one tenth of an inch in diameter, and three inches in length, being ſtretched with weights, is obſerved to ſuſtain 270 pounds before it is broken.

Exp. V.

Plane ſurfaces of hard bodies, being poliſhed and brought into contact, ſtrongly cohere.

Exp. VI.

Bodies by their vis inertiæ are obſerved to reſiſt the impulſes of any force tending to ſet them in motion.—Bodies in motion, reſiſt the impulſes of any force tending to augment or diminiſh their motion.

Exp. VII.

A body any how attracting another body, is attracted by it with equal force. Bodies tending toward each other, by their mutual attraction, move with velocities, which are inverſely as their quantities of matter.

The earth attracts the moon, and is equally attracted by it.— The quantity of matter in the earth is about forty times greater than that contained

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tained in the moon; whence, if theſe bodies were to approach each other in a right line by means of their mutual attraction, while the earth moved toward the moon one mile, the moon would in its approach to the earth deſcribe forty miles. And their relative velocities being always as 40 to 1 they would at length meet impinging againſt each other in contrary directions, and with equal moments.

Exp. VIII.

If a piece of gold and a feather fall at the ſame inſtant from the top of a glaſs receiver, well exhauſted of air, it is obſerved that they both deſcend to the bottom of the receiver in the ſame time.

It appears from hence that bodies are attracted toward the earth with forces not proportional to their bulks, but to the quantities of matter contained in them: for ſuppoſing the weight of the guinea to be a thouſand times greater than that of the feather, it will require 1000 times greater force to move the guinea than the feather, through the ſame ſpace in the ſame time.

Exp. IX.

If two forces act at once upon a body in the direction of the ſides of a parallelogram, and are proportional to them in quantity, it is obſerved that a force oppoſed in the direction of the diagonal, and proportional to it, will counterpoiſe the other two, and the body acted upon will remain at reſt.

Exp. X.

If a body be acted upon by three forces, repreſented in quantity and direction by the three ſides of a triangle; or by four forces, repreſented in quantity and direction by the four ſides of a trapezium, it will be at reſt.

Exp. XI.

A body, or ſyſtem of bodies, will not be at reſt unleſs their center of gravity is ſupported.

The center of gravity of an body or ſyſtem of bodies, is that point in which the weight of the whole is collected, and conſequently will deſcend to the loweſt point poſſible.

Exp. XII.

If any plane figure be placed upon a point or fulcrum, it will not reſt in any poſition whatſoever, unleſs the centers of ſuſpenſion and gravity coincide.

Exp. XIII.

If a body hang freely from a center of ſuſpenſion, it will not be at reſt, except when the line of direction produced paſſes thro' the center of ſuſpenſion.

Exp. XIV.

If a body vibrate freely round different centers of ſuſpenſion, the interſection of lines drawn from thoſe centers perpendicular to the horizon, when the body is at reſt, will be the center of gravity.

Exp. XV.

Bodies may be conſtructed in ſuch a manner, that they may appear to aſcend while their centers of gravity deſcend.

Exp. XVI.

Let two bodies, of any given magnitude and weight, be connected together by a rod, and let them revolve in an horizontal plane round different points in the rod; it is obſerved that the center of gravity will not be quieſcent, unleſs the center of motion coincides with it.

The centrifugal forces of the two bodies revolving round a point in the rod will not be equal, unleſs the centers of motion and gravity coincide.

Exp. XVII.

If a cylinder be placed upon an horizontal plane, the line of direction being without the baſe, the cylinder will fall; but if the plane is elevated in ſuch a manner, that the line of direction may fall within the baſe, the cylinder will be ſupported.

Exp. XVIII.

If ſolids of any kind be placed upon an inclined plane, when the lines of direction always fall without their baſes, they will roll down the plane; if the lines of direction fall within the baſes, and the ſurfaces be ſmooth, the ſolids will ſlide down.

Exp. XIX.

Let weights be ſuſpended on a rod in the following manner: three ounces at ſeven inches from either extremity, four ounces at ten inches, and one ounce at eleven inches; then the diſtance of the center of gravity from the ſame extremity is $\frac{7\times3+4\times10+1\times11}{3+4+1} = 9$ inches.

Exp. XX.

If a rod be ſo conſtructed, that a line joining the centers of gravity and ſuſpenſion may be at right angles to it, the rod hanging freely upon its center of ſuſpenſion, will not be at reſt, except in an horizontal poſition.

Exp. XXI.

A weight which counterpoiſes an ounce when ſuſpended from the longer arm of a falſe balance, being added to the weight which counterpoiſes an ounce ſuſpended from the ſhorter arm, the ſum is obſerved to be greater than two ounces.

Exp. XXII.

Exp. XXII.

Let a ſmooth ſurface, loaded with weights, be placed upon an immoveable horizontal plane: if both ſurfaces be hard and well poliſhed, an horizontal force nearly equal to one third of the weight with which the upper ſurface is loaded will juſt move it along the plane.

Exp. XXIII.

Let two ſurfaces be placed upon an immoveable horizontal plane, and be loaded with equal weights; equal forces will be required to move them along the plane; but if the weights are different, the greater weight will require a greater force to move it, whatever be the proportion of the ſurfaces.

Exp. XXIV.

If a pendulum vibrate upon friction wheels, a given motion communicated to it will not be ſo ſoon deſtroyed, as when it is ſuſpended on an immoveable fulcrum.

The effects of friction may be eſtimated two ways.

1. By the quantity of motion loſt in a given time.
2. By the time in which a given quantity of motion is deſtroyed; the latter method is made uſe of in the experiment.

Exp. XXV.

There will be an equilibrium on a ſtrait lever of any kind, when the power is to the weight, as the diſtance of the weight to the diſtance of the power from the fulcrum.

For if not, let one of the weights preponderate.—Therefore the preponderateing weight has more moment than the other; but ſince by the hypotheſis, the weights are inverſely as the arms of the lever, it follows, that the velocities of the weights are inverſely as their quantities of matter; whence the moments of both are equal: but they were proved unequal. This contradictory concluſion reſults from denying the propoſition affirmed, which is therefore true. The ſame method of demonſtration may be extended to all the mechanical powers.

Exp. XXVI.

There will be an equilibrium upon a bent lever, when the power and the weight are inverſely proportional to the lines drawn from the fulcrum perpendicular to the lines of direction.

Exp. XXVII.

If weights be ſuſpended on the arms of a ſtrait lever, there will be an equilibrium, when the ſum of the products of each weight multiplied into its reſpective diſtance from the fulcrum, on one ſide, is equal to the ſum of the products taken in a ſimilar manner on the other.

Exp. XXVIII.

The ſame moment is produced on the arm of a ſtrait lever, whether weights are ſuſpended at any given diſtances from the fulcrum; or the ſum of the weights is ſuſpended at the diſtance of their common center of gravity.

Exp. XXIX.

On a fixed pulley there is an equilibrium, when the power is equal to the weight.

Exp. XXX.

On a ſingle moveable pulley, there will be an equilibrium, when the power is to the weight, as one to two.

Exp. XXXI.

There will be an equilibrium in a ſyſtem of pullies, where the ſame ſtring goes round all the pullies contained in two blocks, when the power is to the weight, as unity is to the number of ſtrings at the lower block.

Exp. XXXII.

There will be an equilibrium in a ſyſtem of moveable pullies, where a ſeparate ſtring goes round each pulley; when the power is to the weight, as unity to that power of two, whoſe index is the number of pullies.

Exp. XXXIII.

There will be an equilibrium in that ſyſtem of pullies, where the ſtring which goes round each pulley is fixed to the weight; when the power is to the weight, as unity to that power of two, whoſe index is the number of pullies, the whole being decreaſed by unity.

Exp. XXXIV.

When the reſiſtance which acts againſt a wedge is perpendicular to the ſides, there will be an equilibrium, if the power be to the weight, as the back of the wedge is to the ſum of the ſides.

Exp. XXXV.

There will be an equilibrium on the ſcrew, when the power is to the weight, as the diſtance between two contiguous threads, to the circumference which the power deſcribes.

Exp. XXXVI.

There will be an equilibrium on the wheel and axle, when the power is to the weight, as the radius of the axle to the radius of the wheel.

Exp. XXXVII.

If a weight be ſuſtained upon an inclined plane, by a power which acts in a direction parallel to the plane, the power will be to the weight, as the height of the plane to the length.

Exp. XXXVIII.

If a weight be ſupported on an inclined plane, by a power which acts in a direction parallel to the baſe, the power will be to the weight, as the height of the plane to the baſe.

Exp. XXXIX.

If a weight be ſuſtained upon an inclined plane by a power which acts in a direction any how inclined to the plane, the power will be to the weight, as the ſine of the plane's elevation to the coſine of the angle, in which the direction of the power is inclined to the plane.

Exp. XL.

On a compound lever, there will be an equilibrium, when the power is to the weight, as the product of the powers on each lever, to the product of the weights.

The general rule for determining when there will be an equilibrium on a machine, compounded of any number of mechanic powers, is this: —Set down the ratios of the power to the weight on each mechanical power; the ſum of theſe will be the ratio of the power to the weight, when there is an equilibrium on the machine.

Exp. XLI.

An ivory ball impinging directly againſt a quieſcent ivory ball of equal weight, communicates to it nearly the whole velocity of the impact, and after the ſtroke remains almoſt quieſcent.

Exp. XLII.

Let the centers of any number of contiguous ivory balls, equal in weight, be placed in a right line; and let the firſt impinge againſt the next to it in the direction of the line joining the centers: It is obſerved that the ball moſt remote from the ſtroke flies off with a velocity, nearly equal to that of the ſtriking ball, which, with the intermediate balls, remains almoſt quieſcent.

Exp. XLIII.

An ivory ball impinging directly againſt a quieſcent ivory ball of twice the weight, communicates to it nearly two thirds of the velocity with which the impact is made.

Exp. XLIV.

If an elaſtic ball impinge directly againſt a quieſcent elaſtic ball of greater weight, the ſtriking ball will be reflected. If a heavier ball ſtrike againſt a lighter one at reſt, both the balls, after the impact, will go on in direction of the ſtroke.

Exp. XLV.

If two unequal weights be ſuſpended by a line joining them, and going over a fixed pulley, the heavier weight will preponderate; and in its deſcent will deſcribe ſpaces which are as the ſquares of the times of falling from reſt.

If a body fall freely by the force of gravity, it will deſcribe fifteen feet in one ſecond, and ſixty-four feet in two ſeconds of time: The velocity of this motion, is too great for any obſervation to be made in the proportion of the times of deſcent and ſpaces deſcribed, unleſs the body falls from very great altitudes; but in this experiment, the abſolute force of gravity being diminiſhed, the velocity likewiſe will be ſo much diminiſhed, that the proportions of the times of falling, and of the ſpaces deſcribed, will be eaſily aſcertained during the deſcent through ſmaller altitudes.—If the weights be a and b, the ſpace deſcribed by the preponderating weight, will be $16t^2 \times \frac{a-b}{a+b}$ feet in t ſeconds; wherefore if $a = 8\frac{1}{4}$ ounces, and $b = 8$ ounces, the heavier of theſe will deſcend through about three inches in one ſecond, 3×4 inches in two ſeconds, 3×9 inches in three ſeconds, and ſo on, making allowance for the loſs of motion ariſing from friction, which muſt be very much diminiſhed in order to make the experiment nearly correſpond with the theory.—Some uſeful practical rules may be derived from the theory of bodies falling freely by the force of gravity. Suppoſe the ſpace deſcribed by a bodv falling from reſt in one ſecond, to be ſixteen feet, which it is nearly; (and the reſiſtance of the air will being it ſtill nearer:) let s be any ſpace deſcribed in feet, v the velocity acquired at end of the deſcent in feet, t in the time of falling in ſeconds; and we have $s = 16t^2$, $s = \frac{v^2}{64}$, $v = 8\sqrt{s}$, $v = 32t$, $t = \frac{\sqrt{s}}{4}$, $t = \frac{v}{32}$.

Hence having given any one of theſe; viz. either the time of deſcent, the ſpace deſcribed, or velocity acquired by a body which has fallen from reſt, the other two may be readily determined.

Exp. XLVI.

If two bodies begin to deſcend from the higheſt point of an inclined plane at the ſame inſtant, one of them will fall through the perpendicular height, while the other deſcends on the plane to the interſection of the perpendicular drawn from the oppoſite angle.

Exp. XLVII.

If bodies deſcend along inclined planes which have the ſame height, the times of deſcent will be as the lengths of the planes.

For the times of deſcribing different inclined planes are directly as the lengths of the planes, and inverſely as the ſquare roots of their perpendicular heights; The heights being the ſame in this experiment, it follows that the times of deſcription will be as the lengths.

Exp. XLVIII.

If two pendelums be equal in length, it is obſerved, that they deſcribe equal arcs in equal times, whatever be the proportion of their weights.

From hence we infer that gravity acts upon bodies with forces proportional to their quantities of matter.—For ſince the two pendulums vibrate through the ſame ſpace, in the ſame time, it follows that gravity muſt act upon the heavier with a force proportionally greater than that, with which it impels the lighter.—*Vide* Exp. VIII.

Exp. XLIX.

If two pendulums be equal in length, it is obſerved that they deſcribe ſmall circular arcs in nearly the ſame time, whatever be the proportion of the arcs.

Whenever the forces which accelerate bodies are proportional to the ſpaces to be deſcribed, the times of deſcribing thoſe ſpaces will be equal. —In the preſent caſe, the forces which accelerate the pendulums are as the ſines of their angular diſtances from the loweſt point; and the arcs being ſmall, the ratio of their ſines will be nearly the ſame, as that of the arcs themſelves, or of the ſpaces to be deſcribed. Whence it follows, that the ſemi-vibrations of the pendulums moving through the different arcs, and conſequently the entire vibrations, will be deſcribed in nearly equal times.

EXP. L.

If the lengths of two pendulums be as four to one, it is obſerved that their times of vibration in the ſmall arcs of a circle are as two to one.

EXP. LI.

Let a cylindrical rod vibrate in a vertical plane on one of its extremities, as an axis of motion: a pendulum, the length of which is two thirds of the cylindrical rod, will vibrate in the ſame time.

The center of oſcillation is that point, in which all the moment of a body revolving round a center of motion is collected; in a cylindrical rod, vibrating round one of it's extremities, this point is diſtant two thirds of the whole length from the center of motion.—The diſtance of the center of oſcillation from the center of motion determines the length of a pendulum.

EXP. LII.

In a compound pendulum, as the center of ſuſpenſion is brought nearer to the center of gravity, the diſtance of the center of oſcillation from the center of ſuſpenſion increaſes ſine limite.

Let a compound pendulum conſiſt of two weights, *A* and *B*, fixed at the extremities of a rod; and let the diſtances of *A* and *B* from the center of ſuſpenſion be *a* and *b* reſpectively: If the weights be on the ſame ſide of the center of ſuſpenſion, the diſtance of the center of oſcillation from it will be $\frac{Aa^2 + Bb^2}{Aa + Bb}$; if the weights be on different ſides of the center of ſuſpenſion, the diſtance of the center of oſcillation will be $\frac{Aa^2 + Bb^2}{Aa - Bb}$: in this caſe when $Aa = Bb$, the center of gravity coincides with the center of ſuſpenſion, and the diſtance of the center of oſcillation from it becomes $\frac{Aa^2 + Bb^2}{0}$, which is infinite.

Exp. LIII.

If the baſe of an inverted cycloid be parallel to the horizon, and bodies deſcend from different points of the arc to the loweſt point, it is obſerved that the times of deſcent are equal.

The forces which accelerate bodies deſcending on the cycloidal arc in the poſition as deſcribed in the experiment, are as the ſpaces to be deſcribed, whence the times of deſcent through them muſt be equal to each other.

Exp. LIV.

If two bodies fall from reſt at the ſame inſtant, the one deſcribing the inverted ſemicycloid, the other deſcending in a right line joining the extremities of it, the body which deſcribes the curve, will arrive at the loweſt point before that which deſcends along the right line.

The cycloid is called from this property, the line of ſwifteſt deſcent.

Exp. LV.

Bodies projected near the ſurface of the earth, in any direction not perpendicular to the horizon, deſcribe a parabola.

Experiment will not exactly agree with the theory of projectiles, unleſs the reſiſtance of the air be taken into conſideration; but the difference is not conſiderable. Some uſeful practical rules may be deduced from the principles of projectiles: In experiments made on the ſtrength of powder, and other circumſtances relating to gunnery, the angle of elevation, or the firſt direction of the project is uſually 45°, in which caſe the time of flight being given by obſervation; the horizontal range, the greateſt altitude, and the velocity of projection will be readily aſcertained.

Let a = the greateſt altitude of the project
v = the velocity of projection } in feet.
b = the horizontal range
t = the time of flight in ſeconds
then t being given we ſhall derive from it

$$a = 4t^2$$
$$b = 16t^2$$
$$v = t \times \sqrt{512}$$

Exp. LVI.

If the velocity of projection be given, the horizontal range is greateſt when the angle of elevation = 45°.

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HYDROSTATICS.

EXPERIMENT I.

LET a glaſs veſſel filled with water, be weighed in air; being afterwards weighed in water, it appears to loſe the greater part of its weight.

Before the principles of Hydroſtatics were fully underſtood, this experiment induced philoſophers to imagine, that fluids were deprived of their weight when immerſed in fluids of the ſame ſort.—The true reaſon of this apparent loſs of weight will appear in the ſucceeding experiments.

EXP. II.

Let a hollow ſphere be made heavy enough to ſink in water, and let it be weighed when immerſed: being filled with water, and again weighed when immerſed, it is obſerved to be heavier than before, by the weight of the included water.

This experiment is a direct proof, that a fluid, when immerſed in its own element, loſes no part of its weight.

EXP. III.

Let mercury be poured into tubes, open at both ends, and bent at different angles; upon immerſing the ſhorter arms in water, it is obſerved, that the mercury in all the longer arms is elevated.

One of the principal properties of fluids is their preſſure in all directions, which is demonſtrated by this experiment.

Exp. IV.

Let a piece of cork be fitted to the bottom of a veſſel, ſo that the ſurfaces may be every where in contact. If mercury be poured into the veſſel, the cork will not aſcend, till the ſurface of it is ſeperated from the bottom of the veſſel.

Cork being immerſed in mercury, is preſſed upwards with a force which is greater than its weight, and muſt therefore aſcend, unleſs the communication between its lower ſurface and the fluid is prevented: this is effected in the experiment; by which means the cork remains attached to the bottom of the veſſel, partly by its own weight, and partly by the weight of the mercury preſſing on its upper ſurface.

Exp. V.

Let oil be poured into a bent tube, open at both ends; upon immerſing the ſhorter arm in water, it is obſerved that the oil aſcends in the longer arm, and deſcends in the other.

This experiment is intended to prove, that a heavier fluid may gravitate upon a lighter.

Exp. VI.

Let a tube, open at both ends, be immerſed in mercury, contained in a glaſs veſſel; if water be poured into the veſſel, it is obſerved that the mercury will riſe in the tube.

This experiment proves, that a lighter fluid may gravitate upon a heavier.—It is alſo concluded, from hence, that however light a fluid may

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be, a ſufficient quantity of it preſſing upon the ſurface of a heavier fluid, may raiſe it up an immerſed tube, with the inſide of which, the lighter fluid does not communicate.

Exp. VII.

If any number of tubes, however differing in dimenſion and figure, communicate with each other, ſo that a fluid being poured into one of them, may flow into the others, it is obſerved, that the ſurfaces of the fluid, in all the tubes, are on a level.

Exp. VIII.

Let the ſhorter arm of a ſyphon be immerſed in mercury; if the air be removed from the inſide of the tube, it is obſerved, that the mercury will flow out of the longer arm, in a continued ſtream.

It may be inferred from the preceding experiments, that the gravitation of bodies toward the center of the earth is not confined to thoſe which are uſually called heavy, but extends to matter in general; and that the terms heavy and light are merely relative expreſſions.

The relative weights of ſubſtances, or their ſpecific gravities, are meaſured by the abſolute weights contained in bodies of equal magnitudes: Thus if a cubic inch of copper, weighs nine times as much as a cubic inch of water, the relative, or ſpecific gravities of copper and water, will be as nine to one. From hence may be derived theſe general rules:

1. The weights of bodies are proportional to their magnitudes and ſpecific gravities jointly.
2. The magnitudes of bodies are as their weights directly, and ſpecific gravities inverſely.
3. The ſpecific gravities of bodies are as their weights directly, and magnitudes inverſely.

Exp. IX.

Let a circular plate of braſs be exactly fitted, ſo as to cover the lower aperture of a cylindrical tube immerſed perpendicularly in water,

water.—If the plate be immerſed to a depth of eight times its own thickneſs, it will be juſt ſupported by the preſſure of the water.

The weight of the braſs, is equal to the weight of eight times its bulk of water; whence the preſſure on it muſt be equal to the weight of a column of water, whoſe baſe is the ſurface preſſed upon, and altitude its perpendicular diſtance from the ſurface of the water.

Exp. X.

Let a tube (open at both ends) be inſerted into a cloſed cylindrical veſſel. If water be poured in, ſo as to riſe in the tube to any altitude, it is obſerved, that the preſſure which the baſe of the veſſel ſuſtains, is equal to the weight of a cylinder of water, whoſe baſe is the ſurface preſſed upon, and altitude the ſame as that of the water in the tube.

We obſerve from this experiment, that the quantity of preſſure upon the baſe is much greater than the weight of the fluid contained in the tube and veſſel, which has been eſteemed a paradox, but will be eaſily accounted for by obſerving, that if an aperture were made in the top of the incloſed veſſel, the water by its preſſure upward, would riſe to nearly the ſame level with that in the tube; whence the water being confined by the upper part of the veſſel muſt preſs againſt the baſe with an equal force, action and re-action being equal; ſo that the preſſure ſuſtained by the baſe, conſiſts both of the weight of the fluid, and its re-action againſt the upper ſurface of the veſſel.

Exp. XI.

If a ſolid float upon the ſurface of a fluid, it is obſerved, that the fluid diſplaced is equal in weight to the ſolid.

From this experiment we may derive the following concluſion: Since the ſpecific gravities of bodies are as their weights directly, and magnitudes inverſely; if their weights are equal, the ſpecific gravities muſt be inverſely as their magnitudes.—The weight of the water diſplaced, and of the ſolid, are equal by the experiment; wherefore the magnitude of the water diſplaced, muſt be to that of the ſolid, as the ſpecific gravity of the ſolid, to the ſpecific gravity of the fluid ; or, in other words, the part immerſed is to the whole, as the ſpecific gravity of the ſolid, to the ſpecific gravity of the fluid. Hence it appears, that ſhips diſplace a quantity of water equal in weight to that of the ſhip and its loading—if a quantity of water be let into the cavity of the ſhip, ſo as to make the weight of the whole, greater than the weight of an equal bulk of water, the ſhip will ſink.

EXP. XII.

If a cylinder, ſeven inches in length, the ſpecific gravity of which is nine times greater than that of water be immerſed in mercury ; 2.5 inches of it will remain above the ſurface.

From the laſt experiment, the part immerſed, is to the whole as the ſpecific gravity of the ſolid to the ſpecific gravity of the fluid ; or in the preſent caſe, as the part immerſed : 7 :: 9 : 14 Wherefore the part immerſed $=\frac{9\times7}{14}=4.5$: And the part remaining above the ſurface $=2.5$ inches.

EXP. XIII.

If a cylinder of elm, (or any other ſubſtance of the ſame ſpecific gravity) ten inches inlength, be immerſed perpendicularly in water, the part remaining above the ſurface is obſerved to be four inches.

2. If the ſame cylinder be immerſed in ſpirit of wine, the part remaining above the ſurface is only three inches.

Upon this principle the hydrometer is conſtructed.—For the ſpecific gravity and magnitude of the ſolid, continuing the ſame, we ſhall have the ſpecific gravity of the fluid inverſly as the part immerſed ; if therefore the cylinder be graduated, the depth to which it ſinks when immerſed in different fluids, will ſhew their relative or ſpecific gravities : Thus the depth to which it ſunk in water, was obſerved to be ſix inches, in ſpirits of wine ſeven inches ; wherefore the ſpecific gravity of water, is to that of ſpirits of wine, in an inverſe proportion of thoſe numbers ; or, as 7 to 6, or as 1 to .857.

Exp. XIV.

Let a cylinder, ſeven inches in length, the ſpecific gravity of which is nine times greater than that of water, be immerſed in mercury; 2.5 inches of the cylinder will remain above the ſurface. If water be poured on the mercury till it covers the cylinder, 2.7 inches will now remain above the ſurface.

It followed from a preceding experiment, that if a ſolid floated upon the ſurface of a fluid, the part immerſed would be to the whole, as the ſpecific gravity of the ſolid to the ſpecific gravity of the fluid: and upon this principle, the part of the cylinder which remained above the ſurface of the mercury, was at firſt 2.5 inches; but by pouring on water, the cylinder was raiſed, ſo that 2.7 inches remained above the ſurface.—Hence the prior rule for finding the proportion of the part of a ſolid immerſed to the whole, will be accurately true only in vacuo. The rule for determining this proportion, in the preſent caſe, is as follows: as the part immerſed is to the whole, ſo is the difference of the ſpecific gravities of the ſolid and lighter fluid, to the difference of the ſpecific gravities of the heavier and lighter fluids.

It appears from hence, that if any ſubſtance float upon the ſurface of a fluid in vacuo, upon admitting the air, the floating body will riſe higher above the ſurface, ſo that the proportion of the part immerſed to the whole will be ſomewhat leſs than before.—The difference of the parts of a ſolid immerſed in a fluid, when in vacuo and in open air, may be eſtimated in general thus:

Let m = the magnitude of the ſolid
s = its ſpecific gravity
A = the part immerſed when in open air
B = the part immerſed when in vacuo
a = the ſpecific gravity of the fluid in which the ſolid is immerſed.
g = the ſpecific gravity of the air.

Then by the firſt rule $B . m :: s : a$; and $B = \frac{m \times s}{a} =$ to the part immerſed when in vacuo.

By the latter rule $A : m :: s-g : a-g$; whence $A = m \times \frac{\overline{s-g}}{a-g} =$ to the part immerſed when in air: and the difference of the parts immerſed occaſioned by the air's preſſure $= B - A = \frac{m \times s}{a} - \frac{m \times \overline{s-g}}{a-g} =$

$$\frac{m \times \overline{sa - sg - sa + ag}}{a^2 - ag} = \frac{mg \times \overline{a-s}}{a^2} \text{ nearly.}$$

Hence we may infer by making the computation, that the weight of the air incumbent on the ſurface of water, whereon a body floats, makes ſo little difference in the proportion of the part immerſed to the whole, that it may be neglected in any eſtimate of this kind, except where the utmoſt accuracy is required.

Exp. XV.

A ſolid is obſerved to weigh leſs when immerſed in Water, than in open Air, by the weight of a quantity of water equal in bulk to the ſolid.

All ſolids deſcend in a fluid with forces leſs than their weights; and the difference appears by the experiment, to be the weight of a quantity of the fluid, equal in bulk to the ſolid. By means of this principle, the relative weights or ſpecific gravities of bodies are determined. The rule is this: Let the ſolid be weighed in air and in any fluid.—Then as the whole weight is to the difference of the weights, ſo is the ſpecific gravity of the ſolid to the ſpecific gravity of the fluid.

Exp. XVI.

A cubic ~~is~~ inch of any ſubſtance which will ſink in Water, being immerſed in it, weighs leſs by 253.2 grains than when it is weighed in air.

From this experiment is deduced a concluſion, which greatly facilitates the computation of the ſpecific gravities, magnitudes, and weights of bodies: The weight which the cubic inch loſes, in water, appears from the preceding experiment to be the weight of a cubic inch of water, which is therefore $=253.2$ grains: conſequently a cubic foot of water or 1728 inches $=253.2\times1728=437500$ grains nearly, or 1000 ounces. Let $w=$ the weight of a body in ounces; s its ſpecific gravity, taken in that ſcale, where the ſpecific gravity of water $=1000$; m its magnitude, in parts of a cubic foot; and we have the following proportion:

$$1000 :: w :: 1000\times1 :: m\times s$$

or, as the number of ounces contained in a cubic foot of water, is to the number of ounces contained in the ſolid, ſo is the ſpecific gravity of the cubic foot of water × into its magnitude, to the product of the ſpecific gravity and magnitude of the ſolid: whence $w=\frac{1000\times ms}{1000}=ms$.

Example. To find the weight of 2.16 cubic inches of braſs. Here $m=\frac{2.16}{1728}$ parts of a cubic foot: $s=8000$: and $w=m\times s=\frac{2.16\times8000}{1728}$ $=10$ ounces.

Example 2. To find the magnitude of a quantity of air, which weighs an ounce:

Here $w=1$; $s=\frac{1000}{860}$; and $m=\frac{w}{s}=\frac{860}{1000}=.86$ parts of a cubic foot, the magnitude required.

Exp. XVII.

If a very thin veſſel be weighed when full of air, and when exhauſted, the difference of weights is obſerved to be nearly $\frac{2}{7}$ of a grain for every cubic inch contained in the veſſel.

Exp. XVIII.

Let a piece of cork be exactly counterpoiſed in a ballance by a leaden weight: if the whole be placed under the receiver of an air pump, upon exhauſting the air, the cork will preponderate.

Since all bodies deſcend in vacuo with forces which are proportional to their quantities of matter, or their weights, it follows that two bodies which counterpoiſe each other in vacuo, contain accurately equal quantities of matter; but when a body deſcends in a fluid of any kind, (not tenacious) its force of deſcent is diminiſhed by the weight of a quantity of fluid equal in magnitude to the ſolid. Hence it follows that the air's preſſure diminiſhes the weight of the cork more than it does that of the lead; whence theſe ſubſtances, being counterpoiſed in air, will not contain equal quantities of matter; and the air being removed, the weight which is really the greateſt muſt preponderate.

We learn from hence that the true weights of bodies are not obtained by weighing in air, unleſs the body to be weighed, and the weight, are of the ſame ſpecific gravity.

Exp. XIX.

If a piece of copper be exactly counterpoiſed in air by a braſs weight, and both the copper and braſs be immerſed in water, the copper will preponderate.

The principle upon which this experiment depends, is this: the water preſſes upward with greater force againſt that body, which is the greateſt in magnitude; whence the braſs will loſe more weight than the copper, which muſt therefore preponderate. Let any two bodies of equal weight, but different ſpecific gravities, be immerſed in a lighter fluid; the following proportion, derived from the principles of ſpecific gravities, will determine how much greater weight is loſt by the one than by the other: as the product of the ſpecific gravities, is to their difference, ſo is the weight of either ſolid × into the ſpecific gravity of the fluid, in which the ſolids are immerſed, to the difference of weights required.

Example. If 120 grains of braſs be counterpoiſed in air by a copper weight; upon immerſing them in water, the equilibrium is deſtroyed: the weight which muſt be added to the ſcale from which the braſs is ſuſpended, in order to reſtore the equilibrium, will be determined by referring to the rule:

As $9 \times 8 : 9 - 8 :: 120 \times 1 : \frac{120}{72} =$ one grain and two thirds, the weight required.

Example 2. If a guinea weighing 129 grains be counterpoiſed in air by a braſs weight, and both be immerſed in water, $\frac{129 \times \overline{17.2 - 8}}{8 \times 17.2}$ [illegible] or ſomething more than 8½ grains muſt be added to the ſcale from which the braſs is ſuſpended in order to reſtore the equilibrium which is deſtroyed by the immerſion.

Exp. XX.

The ſpecific gravity of a body which will not ſink in water may be determined by uniting it to a ſolid, ſo that the compound may be ſpecifically heavier than water.

This method of determining ſpecific gravities may be expreſſed generally thus:

Let $A =$ the weight of the heavier ſolid
$a =$ its ſpecific gravity
$B =$ the weight of the lighter ſolid
$x =$ its ſpecific gravity ſought
$C =$ the weight of the compound
$c =$ its ſpecific gravity.

Then from the principles of ſpecific gravities, we have $\frac{A}{a} + \frac{B}{x} = \frac{C}{c}$ whence $x = \frac{Bac}{Ca - Ac}$, the ſpecific gravity required.

Exp. XXI.

Let a glaſs tube, 36 inches in length, be filled with mercury, and one extremity being cloſed, let the other be immerſed in a veſſel of mercury; it is obſerved, that the mercury ſinks from the upper end of the tube, and remains ſuſpended at an altitude of about twenty-nine inches and a half.

Exp. XXII.

A tube leſs than twenty-eight inches in length, being filled and immerſed, the the mercury will remain contiguous to the upper end of the tube.

The weight of the mercury in the tube is this caſe leſs than the preſſure of the atmoſphere.

Exp. XXIII.

If barometer tubes, of various dimenſions and inclinations, be filled and immerſed, it is obſerved, that the mercury remains ſuſpended at the ſame perpendicular altitude in them all.

Exp. XXIV.

Let a barometer be placed under the receiver of an air-pump, as the air is exhauſting, the mercury continually deſcends 'till it is nearly on a level with the mercury in the veſſel.—Upon admitting the air, the mercury riſes to its former altitude.

Exp. XXV.

Let a tube, thirty-ſix inches in length, open at both ends, be immerſed in mercury, contained in a veſſel, from the inſide of which the external air is excluded; if the tube and veſſel be placed under a receiver, it is obſerved, upon exhauſting the air, that the mercury is raiſed in the tube nearly to the ſtandard altitude.

It is demonſtrated from this experiment, that the elaſtic force of the air preſſing againſt any ſurface, is equal to the weight of the atmoſphere preſſing upon the ſame ſurface.

Exp. XXVI.

Let a veſſel be filled with water, and the aperture of it be exactly covered with a braſs plate; if the veſſel be inverted, the plate will continue to adhere to it.

Exp. XXVII.

Let a thin glaſs veſſel, the aperture of which is cloſed, be placed under the receiver of an air-pump, if the air be exhauſted from the receiver, the veſſel will be broken.

Exp. XXVIII.

Let a thin glaſs veſſel, the aperture of which is cloſed, be fitted with a valve, opening outwards. If this be placed under the receiver of an air-pump, the air being exhauſted, and re-admitted into the receiver, the veſſel will be broken.

Exp. XXIX.

Let a thin plate of glaſs be fitted to the upper aperture of a receiver, ſo that there be no communication between the internal and external air; upon exhauſting the receiver, the plate of glaſs is broken.

Exp. XXX.

If a barometer be immerſed in a veſſel of mercury, and ſuſpended from the beam of a ballance; it is obſerved that the weight neceſſary to counterpoiſe it, excluſive of the tube, is equal to the weight of the mercury ſuſtained in the barometer, by the preſſure of the atmoſphere.

Exp. XXXI.

Let two hollow braſs hemiſpheres be cloſely placed together ſo as to prevent the communication of the external and internal air; if the air be exhauſted from the cavity, it is obſerved that the hemiſpheres are preſſed together with a force which requires a weight of about fifteen pounds for every ſquare inch of a great circle of the biſſected ſphere to ſeparate them.

Exp. XXXII.

If the exhauſted hemiſpheres be ſuſpended under the receiver of an air-pump, upon exhauſting the air, the lower hemiſphere will fall to the bottom of the receiver.

Exp. XXXIII.

If an exhauſted receiver be made to communicate with a veſſel of water, by means of a tube inſerted in the center of the plate on which the receiver ſtands; the water aſcends through the tube, and ſtrikes againſt the extremity of the receiver with a continued ſtream.

Exp. XXXIV.

Let a glaſs ſphere, having a ſmall orifice made in that part of it which is immerſed, float upon the ſurface of a veſſel of water: if the veſſel be placed under the receiver of an air-pump, upon exhauſting the air, and re-admitting it into the receiver, the ſphere will be filled with water, and ſink to the bottom of the veſſel.

Exp. XXXV.

Warm water, or newly fermented liquors, appear to boil, in vacuo.

Exp. XXXVI.

The ſpaces into which a given quantity of air is compreſſed, are obſerved to be leſs in the ſame proportion, as the forces of compreſſion are greater.

Exp. XXXVII.

Let ten inches of air be included with the mercury in a barometer (exactly cylindrical) of thirty-five inches in length; if the barometer be inverted and immerſed in mercury, the included air will now occupy twenty inches.

From this experiment is derived the following proportion: As the ſtandard altitude is to the defect from it, ſo is the ſpace which the included air occupies after inverſion, to the ſpace it occupied before inverſion.

Let s = the ſtandard altitude
d = the defect from it
b = the difference between the ſtandard altitude and the length of the tube
g = the quantity of air included.

Whence we have in general $s : d :: b + d : g$ and $g = \frac{\overline{b+d} \times d}{s}$

If the quantity of air included be given to find the defect from the ſtandard altitude, put x equal to the defect, and we have by the preceding rule:

$s : x :: b + x : g$. Wherefore $x^2 + bx = sg$; and $x = \frac{\sqrt{b^2 + 4sg} - b}{2}$.

If the ſtandard altitude be greater than the length of the tube, the ſign of b muſt be changed, and the defect from the ſtandard altitude, or x will now be equal to $\frac{\sqrt{b^2 + 4sg} + b}{2}$

The barometer tube being cylindrical, the quantity of air included before inverſion, and the ſpaces occupied after inverſion are eſtimated by the degrees, into which the length of the tube is divided.

A general concluſion is derived from the two preceeding experiments, viz. the elaſtic force of the air is directly proportional to it's denſity, and inverſely as the ſpace which it occupies.

Exp. XXXVIII.

The altitude of the mercury in a barometer, elevated above the ſurface of the earth, is obſerved to be leſs than the ſtandard altitude.

Since the ſuſpenſion of the mercury in the barometer, has been proved to ariſe from the preſſure of the atmoſphere, it follows, that if any part of the airs weight ſhould be taken off, the altitude of the mercury in the tube will be diminiſhed.—The following rule will determine the height of a mountain by means of the barometer: (ſetting aſide the effects of the different temperatures of the air.)—Let the altitude of the mercury in the barometer at the bottom of the mountain be a, the altitude at the top b; the height required will be $= \log. \frac{a}{b} \Big| \times \frac{10}{6}$ in parts of a mile.

The log. of $\frac{a}{b}$ is here ſuppoſed to be *Briggs*'s.

Exp. XXXIX.

If a tube be immerſed in a fluid, and the air contained in the tube be rarefied, the fluid will riſe in it.

This

This experiment is ſimilar to Exp. XXV. but is immediately deſigned to explain the operation of pumps in raiſing water: theſe inſtruments, however various in their conſtruction, all depend upon the ſame principles, viz. the weight and elaſticity of the air.

Exp. XL.

If a tube, open at both ends, be immerſed in water, the ſurface of which is contiguous to air, compreſſed into one half the ſpace, which it poſſeſſes in the atmoſphere, the water will ſpout from the tube when placed vertically, to an altitude of about thirty-three feet, ſetting aſide the effects of friction, and the reſiſtance the air.

Exp. XLI.

If a bell be ſtruck under the receiver of an air-pump, it is obſerved that the ſound becomes weaker the more the air is exhauſted.

It appears from this experiment, that ſound is propagated by the air; but on account of the parts of the apparatus which communicate with the bell, ſome ſound will always be perceived, though the air is as much exhauſted as poſſible.

Exp. XLII.

Flame is obſerved to be extinguiſhed in vacuo. If it be placed under a cloſe receiver, it will be extinguiſhed after ſome time, although the air be not exhauſted.

Exp. XLIII.

If water flows out of equal apertures made in the ſides of cylindrical veſſels, and the veſſels be kept conſtantly filled, it is obſerved that the quantity of water diſcharged in a given time is in a direct ſubduplicate ratio of the perpendicular diſtance of the apertures from the ſurface of the water.

Exp. XLIV.

If an aperture biſſects the altitude of a cylindrical veſſel, kept conſtantly filled with water, the horizontal diſtance to which the water ſpouts, is equal to the height of the veſſel, ſetting aſide the effects of friction, and the reſiſtance of the air.

Exp. XLV.

If apertures be made at different diſtances from the ſurface of the water contained in a cylindrical veſſel kept conſtantly filled, the horizontal diſtance to which the fluid ſpouts, is obſerved to be the greateſt when the aperture biſſects the diſtance between the ſurface of the water and baſe of the veſſel.

In general, let A be the altitude of the veſſel, D the diſtance of the aperture from the ſurface, then the parameter of the parabola deſcribed by the fluid, will be $4D$, the abſciſſa $= A - D$: And the ſquare of the ordinate, or of the horizontal diſtance is equal to $4AD - 4D^2$, which quantity is the greateſt when $A = 2D$, or when the aperture biſſects the diſtance between the ſurface of the water, and the baſe of the veſſel.

Exp. XLVI.

Let apertures be made at equal diſtances from the bottom, and the top of a cylindrical veſſel kept conſtantly filled with water; the horizontal diſtances to which the water ſpouts from theſe apertures is obſerved to be the ſame.

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ELECTRICITY.

EXPERIMENT I.

IF a glaſs tube made very dry, be rubbed with a piece of ſilk, it is obſerved that light ſubſtances, ſuch as feathers, cork, balls, &c. being applied near to it, are firſt attracted and afterwards repelled.

The power by which theſe light ſubſtances are attracted and repelled, is called Electricity; the ſubſtance by the friction of which it is produced, is ſaid to be electric; the friction of electric bodies, is called excitation.

EXP. II.

Excited ſealing-wax being applied near to light bodies, firſt attracts and afterwards repels them.

Amber, ſilk, jet, dry wood, and a variety of other ſubſtances being excited, attract and repel light bodies, and are called Electrics.—Metals, water and other bodies, the friction of which will not produce this power of attraction, and repulſion, are called Non-electrics.

EXP. III.

If a metalline cylinder be ſupported upon ſilk lines, or upon glaſs, and an excited electric be applied near to it, every part of the cylinder will attract and repel light ſubſtances, in the ſame manner as the excited electric itſelf.

Metals poſſeſſing the power of tranſmitting electricity, are called Conductors; to theſe may be added water, and all bodies which contain it.

EXP.

Exp. IV.

Let a ſilk line, or a glaſs rod made very dry, be ſuſpended on glaſs; it is obſerved that electricity cannot be tranſmitted through either of them.

Glaſs being impervious to electricity is called a Non-conductor. Silk, jet, ſealing-wax, air, &c. are likewiſe Non-conductors; and in general, all bodies which are electrics, are Non-conductors; and all bodies which are Non-electrics, are conductors.

A body which communicates with nothing but electrics, is ſaid to be inſulated.

Exp. V.

Let two cork balls be ſuſpended from lines about ſix inches in length, and inſulated; if excited ſealing-wax or glaſs be applied to them, they will repel each other; and after the excited electric is removed, they are obſerved to remain repelled.

The uſe of inſulating bodies, is to confine the electricity applied to them, and to render the effects of it permanent.

Exp. VI.

Conducting ſubſtances not inſulated, being held near to an excited electric, are obſerved to be attracted towards it.

Definition. — The electric power which is produced from the excitation of glaſs, is called the Vitreous Electricity; and the power which is produced from the excitation of ſealing-wax is called the Reſinous Electricity.

Exp. VII.

If the inſulated cork balls repel each other with the vitreous electricity, the reſinous power being applied to them, will deſtroy that repulſion, and will cauſe the balls to repel each other with the reſinous electricity, if the excitation be ſufficiently ſtrong.

Exp. VIII.

The repulſion of the balls electrified with the reſinous power, is deſtroyed by the application of the vitreous.

Exp. IX.

If glaſs and ſealing-wax equally excited, are at once applied to the inſulated cork balls, no electricity of either ſort will appear to be communicated to them.

We obſerve from the three preceding experiments, that the vitreous and reſinous powers counteract each other; whence if both are applied at once to a body, the electricity communicated upon the whole, will be only the difference of the two, and will be of that ſort which is the ſtrongeſt.

Exp. X.

If bodies be electrified with contrary powers, they are obſerved to attract each other ſtrongly.

General Properties of Electricity.

1. Bodies electrified vitreouſly repel each other.
2. Bodies electrified reſinouſly repel each other.
3. Electrified bodies attract bodies not electrified.
4. Bodies electrified by contrary powers attract each other ſtrongly.

Exp. XI.

If a glaſs tube having it's poliſh taken off be excited, it will communicate the reſinous electricity to bodies held near it.

Exp. XII.

A piece of down being applied to excited ſealing-wax, and touched at the ſame time with a conductor, is electrified with the vitreous power.

It is concluded from this and the preceding experiment, that both reſinous and vitreous powers are produced from the excitation either of glaſs or of ſealing wax.—For the ſake of diſtinction, that power which is produced by the excitation of poliſhed glaſs, will be called vitreous, and the contrary power reſinous.

Exp. XIII.

If the rubber of a glaſs tube or cylinder be inſulated, and a conductor applied to the cylinder while excited, it is obſerved that the rubber is electrified reſinouſly.

Whenever the electric powers are ſeparated by excitation, one power attaches itſelf to the excited electric, and the other to the rubber.

Exp. XIV.

If the rubber and conductor applied to an excited electric, are both inſulated, the leſs electricity will be produced, the more perfect the inſulation is made.

Neither the rubber nor conductor can be inſulated perfectly, on accoun of the moiſture which is always floating in the air.

If the air and the parts of the apparatus be very dry, little or no electricity will be excited in the circumſtances above-mentioned.

It is concluded from hence that the electric powers do not exiſt in the electrics themſelves, but that they are produced from the earth by the excitation of electrics.

An electric ſubſtance contained between parallel ſurfaces, however diſpoſed, is called an electric plate.

Exp. XV.

Electrified bodies attract bodies not electrified, although a thin electric plate be interpoſed between them.

Exp. XVI.

Bodies electrified with contrary powers, attract each other ſtrongly, although an electric plate be interpoſed between them.

Thus flame communicates heat through ſubſtances, which are impervious to the flame itſelf.

HYPOTHESIS.

1. The two electric powers exiſt together in all bodies.
2. Since they counteract each other when united, they can be made evident to the ſenſes, only by their ſeparation.
3. The two powers are ſeparated in nonelectrics by the excitation of electrics, or by the application of excited electrics.
4. The powers cannot be ſeparated in electric ſubſtances.
5. The two electricities attract each other ſtrongly through the ſubſtance of electrics.
6. Electric ſubſtances are impervious to the two electricities.
7. Either power, when applied to an unelectrified body repels the power of the ſame ſort, and attracts the contrary power.

Exp. XVII.

If one ſurface of a plate be electrified with either power, the oppoſite ſurface is electrified with the contrary power, if it be not inſulated.

Either power being applied to one of the ſurfaces, attracts the contrary power through the ſubſtance of the electric, and repels the electricity of the ſame ſort with itſelf.—The two powers being thus brought to the oppoſite ſurfaces of the plate which is impervious to them, remain ſuſpended; ſtrongly attracting each other, till the interpoſed plate is broken by their force, or a communication is formed between the two ſurfaces by ſome conducting ſubſtance.

When the two powers are ſuſpended on the oppoſite ſurfaces of an electric plate; the plate is ſaid to be charged. A conducting ſubſtance which forms a communication between two charged ſurfaces is called a circuit.

Exp. XVIII.

Whenever the two powers unite by breaking a plate of air, an electric light is obſerved, which is attended with an exploſion if the charge be conſiderable; the union of the two electricities deſtroys the effects of each, and leaves the plate diſcharged.

Whenever either power is accumulated in an electric cloud, the ſurface of the earth oppoſed to it is electrified by the contrary power.—Theſe powers ſometimes unite by breaking the interpoſed plate of air.

Exp. XIX.

If plates of air and glaſs equal in magnitude and dimenſion, are charged by equal excitations, the plate of air is obſerved to be much more eaſily broken by the force of the charge, than the plate of glaſs.

Exp. XX.

If inſulated bodies be applied to either ſurface of a charged plate, at different diſtances from it, it is obſerved that the leſs the diſtance, the ſtronger the repulſive power. If bodies not inſulated are applied, the leſs the diſtance from the charged ſurface, the ſtronger is the power of attraction; from whence it is concluded, that the forces of electric repulſion and attraction vary in ſome inverſe ratio of the diſtance.

It appears that every thing elſe being the ſame, a thin electric plate of glaſs will explode with greater force, than a thicker plate, the attraction of the two powers being the ſtronger, the nearer the charged ſurfaces are to each other.

Exp. XXI.

The force of an electric charge is obſerved not to depend upon the ſhape in which the charged ſurfaces of a given magnitude and thickneſs are diſpoſed.

It may be inferred from the preceding experiments, that the force of a charged plate depends upon two things:

1. The quantity of the ſurfaces charged.
2. Their proximity.

When the ſurfaces of an electric plate are charged with a certain quantity of the two powers, it is obſerved that no additional electricity can be communicated to them, however great an excitation is applied for that purpoſe.

Exp. XXII.

If any part of the human body forms a portion of the electric circuit, it is obſerved that the diſcharge is perceived in that part only which forms the communication, unleſs the charged ſurfaces are very great.

Exp. XXIII.

If circuits different in length and of different ſubſtances form a communication between two charged ſurfaces of an electric plate, it is obſerved that the diſcharge will be made through the beſt conductor, whatever be the lengths of the others.

2. If circuits of the ſame ſubſtance be different in length, the diſcharge will be made through the ſhorteſt of them.

3. If the circuits be the ſame in every reſpect, the diſcharge will be made through many of them at the ſame time.

EXP. XXIV.

The times of diſcharging the ſurfaces of an electric plate through the longeſt or ſhorteſt circuits are not ſenſibly different.

Many miles of the earth's ſurface, large tracts of water, &c. have been made a part of the electric circuit, and the diſcharge has been inſtantaneous through them all.

EXP. XXV.

If either ſurface of a charged plate communicate with the earth, the power on the oppoſite ſurface will expand itſelf into a conductor which is contiguous to it, although the conductor be inſulated.

EXP. XXVI.

Let one ſurface of a charged plate be inſulated: although the other communicate with the earth, no diſcharge of either ſurface will follow.

Exp. XXVII.

Let the ſurfaces of an electric plate be very ſlightly charged and inſulated, and let an interrupted circuit be formed; the two powers will be viſible, illuminating the points of the interrupted circuit, and each power will appear to extend farther from the ſurface contiguous to it, the ſtronger charge is communicated to the plate; but if the illuminations on each ſide meet, there will immediately follow an exploſion of the whole charge.

A cylindrical plate is that which is contained between two equal circles, the planes of which are parallel to each other.

Exp. XXVIII.

If a cylindrical plate of air contained in the receiver of an air-pump be charged, it is obſerved that the more air is exhauſted from between the ſurfaces, the more eaſily the two powers will unite.

The diſcharge appears to be made from that ſurface which poſſeſſes the vitreous power.

Exp. XXIX.

If an exhauſted receiver be made part of the electric circuit, and the charge ſhould be not ſufficient to cauſe an exploſion, an electric light will appear to proceed in oppoſite directions from the parts communicating with the vitreous and reſinous ſurfaces.

If two contiguous clouds, very high in the atmoſphere, be electrified with contrary powers, their diſcharge cauſes an appearance ſimilar to the diffuſe light obſerved in the receiver.

Exp. XXX.

The ſtrength of the excitation being the ſame, it is obſerved that a charged plate of air will be the more eaſily broken, the ſmaller quantity of air is interpoſed between the oppoſite ſurfaces.

Hence an electric plate is more eaſily diſcharged through an exhauſted receiver than in the open air, for the more rare the air is made by exhauſtion, the leſs reſiſtance will be oppoſed to the union of the two powers poſſeſſing the oppoſite ſurfaces, and attracting each other through the electric.

PROPOSITION.

The leaſt cylinder, the diameter of which is finite, and the thickneſs evaneſcent, is to the leaſt cylinder, the thickneſs of which is finite, and the diameter evaneſcent, in a greater than any aſſignable ratio.

Exp. XXXI.

The electric powers poſſeſſing the oppoſite ſurfaces of a cylindrical plate of air, whoſe diameter is evaneſcent, will be incomparably leſs reſiſted by the interpoſed electric, than by the thinneſt plate of air contained between two ſurfaces of a finite magnitude.

Exp.

Exp. XXXII.

Let a pointed body be oppoſed to either ſurface of a charged electric plate; it is obſerved that whatever be the magnitude of the ſurfaces or the quantity of electricity, the whole will be ſilently diſcharged if the other ſurface be not inſulated.

There being no reſiſtance to the union of the two powers, there can be no accumulation or condenſation of them.

Hence the diſcharge will be made ſilently and gradually through a current formed between the point and the ſurface oppoſed to it.

Thus when an electric cloud and the ſurface of the earth directly under it are charged with contrary powers, they attract each other through the interpoſed plate of air.—It is obſerved, that whatever be the quantity of the electric powers contained in the oppoſite ſurfaces, the whole is ſilently diſcharged, if the cloud approaches a pointed body communicating with the earth.

If a conical pointed body were inſerted into ſimilar hollow cone, formed in an electrified ſolid, the ſurfaces of the two cones being every where equi-diſtant, no greater diſcharge of the electricites would follow, than if the two conical ſurfaces had been plane and oppoſed to each other at the ſame diſtance.

In order to increaſe the *force* of the charge, a number of electric plates are ſometimes joined together—the uſual method is, to form a communication between the inſides of a number of coated glaſs jars, and another communication between the external coating. Jars ſo diſpoſed are called a battery, the effects of which are exactly ſimilar to thoſe of a ſingle plate of the ſame thickneſs with the jars, and containing the ſame quantity of ſurface.

Exp. XXXIII.

If a large battery be diſcharged through a ſlender piece of wire, the wire will be broken to pieces or melted.

Gunpowder or ſpirits of wine will be fired, if they are a part of the circuit.—And if the diſcharge be made through a ſilver leaf confined between two glaſs planes, the glaſs will be broken to pieces and ſtained by the ſilver, which is driven by the force of the diſcharge, into the ſubſtance of the glaſs.

Exp.

Exp. XXXIV.

If a battery be diſcharged through a quire of paper, a perforation is made through it, and each of the leaves is protruded by the ſtroke from the middle toward the outward leaves.

Exp. XXXV.

If two electric plates be charged, and a communication formed between the vitreous ſide of one, and the reſinous ſide of the other, no diſcharge will follow; unleſs a communication be formed between the other two ſurfaces, at the ſame time.

The natural electricity in the atmoſphere is frequently diſcharged in this manner: Two clouds being electrified with oppoſite powers, the ſurfaces of the earth immediately under them are likewiſe electrified with powers contrary to thoſe in the clouds above them; and the moiſture of earth forming a communication between the two contiguous charged ſurfaces, whenever the two clouds meet there will follow a diſcharge, both of the clouds and the ſurfaces on the earth oppoſed to them.—If the earth ſhould be dry, and conſequently afford a reſiſtance to the union of the two electricities accumulated on its ſurface, there will follow an exploſion in the earth, as well as in the atmoſphere, which will produce concuſſions and other phænomena which have frequently been obſerved to happen in dry ſeaſons, particularly in thoſe climates which are the moſt liable to ſtorms of thunder and lightning.

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MAGNETISM.

EXPERIMENT I.

LET a ſlender iron rod exactly ballanced, be ſuſpended on a point ſo as to revolve freely in a plane parallel to the horizon: If the rod be touched with a loadſtone, one extremity of it will be always directed towards the north.

That power which the loadſtone communicates to iron is called Magnetiſm; a rod of iron poſſeſſed of this power is called a Magnet: Magnetiſm is communicated to iron by magnetical rods, as well as by the loadſtone itſelf: Iron rods alſo become magnetical by friction, by being kept for a long time in the ſame poſition, and by electricity, without any aſſiſtance from the loadſtone or magnets. The magnetical needle does not point exactly to the north, but is obſerved to change it's azimuth; ſometimes pointing toward the eaſt, and ſometimes to the weſt of the meridian. The extremities of a magnet are called Poles. A vertical circle in the Heavens which interſects the horizon in the points to which the magnetical needle, when at reſt, is directed [redacted] is called the Magnetic Meridian.

EXP. II.

If the north pole of a magnet be placed at the point of ſuſpenſion of a needle, and drawn along towards either extremity; that part of the needle which is touched by the magnet, will be directed to the ſouth.

EXP. III.

If the ſouth pole of a magnet be placed to the point of ſuſpenſion of a needle, and drawn along toward either extremity; that part of the needle which is touched, will be directed to the north.

Exp. IV.

Either pole of a magnet is obſerved to attract iron, which is not magnetical.

Exp. V.

The north poles of two magnets repel each other when brought contiguous.

Exp. VI.

The ſouth poles of two magnets repel each other when brought contiguous.

Exp. VII.

The contrary poles of two magnets attract each other ſtrongly.

Exp. VIII.

The northern magnetiſm is obſerved to be deſtroyed by the communication of the ſouthern and *vice verſa.*

It appears from hence, that the two ſorts of magnetiſm operate in ſuch a manner as to counteract each other; that if both be communicated to the arm of a needle, the effect upon the whole will be only the difference of the two; and will be of that ſort which is the ſtrongeſt.

Hence it is eaſy to reverſe the poles of the magnet.

Exp. IX.

Let a needle be exactly ballanced and ſuſpended, ſo as to revolve freely in a vertical plane; if it be made magnetical when horizontal, the north pole will be depreſſed, and the ſouth pole elevated above the horizon.

Exp. X.

The diſcharge of the electric powers through a needle communicates magnetiſm to it, if the charge be ſufficient.

General Properties of Magnetiſm.

1. No ſubſtance is capable of communicating or receiving magnetiſm, except the loadſtone and iron.
2. Every magnet has two poles.
3. Similar poles of magnets repel each other.
4. Either pole attracts iron not magnetical.
5. The contrary poles of magnets attract each other ſtrongly.
6. The properties of electricity and magnetiſm, are, in ſome reſpects analogous to each other.—*vide* Electricity, Exp. X. and XVI.

⁂ A deſcription of the optical experiments, and the aſtronomical propoſitions, will be printed before the lectures on theſe ſubjects begin.

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